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SOME PROBLEMS IN WESTERN FOREST ENTOMOLOGY

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SOME PROBLEMS IN WESTERN FOREST ENTOMOLOGY

by R. A. Salmon

INTRODUCTION

Appropriate remarks.

Limit coverage to California region.

WHY IS THERE A FOREST INSECT PROBLEM?

Each year there are many and varied types of insect caused damage to forest trees in the forested areas of the California region. However, many of those types of damage do not constitute or represent forest insect problems of any great importance. A few do assume an importance which I believe far exceeds that attributed to them by laymen or others not directly concerned in their solution. Of all the forest insect problems, those in which insects are involved in depletions of values and resources existent in the mature ponderosa, Jeffrey, and sugar pine forests of the state are the most important. As Craighead (1) observed in 1925, work in western forest entomology "is largely an effort directed towards the conservation of mature stands of timber, which has been a leading issue in the past, and for some time to come will be an important consideration in entomological activities...".

There are about thirteen and a half million acres of commercial softwood stands in California (2) on which there are about two hundred and thirteen billion board feet of saw timber. Of this about seventy-five billion board feet is in stands of ponderosa, Jeffrey, and sugar pine, which are insect susceptible species. About forty billion feet is in insect resistant redwoods, and ninety-one billion board feet in true firs and Douglas fir. Insect caused damage to the pine timber resources has overshadowed in importance that occurring in stands of other species, chiefly because of current lumber values, not because of the amount of timber that is involved.

Stands on nearly three million acres have been logged and this area now bears second growth stands in various stages of development of a new crop. On some eight and a half million acres the forests are mature or overmature and constitute an important part of the national reserves of timber. These stands have grown to maturity during a period when they were but little used and scarcely needed. They now are being relied upon to meet the needs of many industries dependent on supplies of soft pine lumber.

Current liquidation and utilization of pine reserves is proceeding at a rapid rate. From 1925 through 1939 a total of about ten and a half billion board feet of pine timber was removed from the forests by logging operations. Fire and disease also have taken their toll. Insects have killed about as much timber as logging has utilized, for during the fifteen year period from 1925 through 1939 they are estimated to have destroyed the values in about eleven and a half billion board feet of pine timber. For the state as a whole, the forest picture is not one of balance. For 1938 the U. S. Forest Service (2) estimated that the growth in saw timber stands of California amounted to but 414 million board feet. During the same season the drain from cutting, insects, fire and disease amounted to 2,649 million board feet or 6.4 times the growth.

Thus there is an important forest insect problem in the commercial pine stands of California because:

1. The timber reserves in those stands are needed
2. There is a heavy drain or depletion of those stands.
3. The relatively large proportion of that drain in which forest insects are concerned is sheer waste.

The control or prevention of that waste is the problem. To a considerable extent the work that has been done on that problem in the past and the current efforts to solve it are representative of the character and type of forest insect problems with which western forest entomologists are chiefly concerned.

WHAT IS THE NATURE OF THESE PINE INSECT PROBLEMS?

Western forest insect problems differ from many of the important entomological problems of the country in that they are chiefly concerned with native species of insects attacking native host plants. Exotic species of insects, introduced host plants or unnatural concentrations of host plant materials have not yet been predominating factors. Most of the problems involve long established and natural ecological relations of a number of species of insects to a number of species of host trees. These relations have, probably over several centuries at least, been an important factor in moulding the forests of today to their present form and structure.

Ordinarily, a year's insect caused loss rarely exceeds four or five percent of the merchantable stand. In annual crops or in those requiring but a few years to mature, such a small amount of loss would not be serious. In forest crops such as ponderosa pine, which requires between one and two hundred years to bring to a merchantable state, such losses are important. Naturally in most years losses are offset and exceeded by the growth of the remaining trees. Otherwise there would be no stands today. However, the serious aspect of our current forest insect problems is that in some important areas and during the past fifteen years the records show that annual losses have consistently exceeded annual increments. The loss merely of the amount of growth is equivalent to no profit, but a net loss, added to other net depletions of other years, have produced negative growth balances or net losses which have been recorded as amounting to as much as 87 percent of the stand.

From the start, with the publication of Hopkins' Bulletin 21 (3) in 1899, it is evident that most workers have had a broad conception of the nature of the western forest insect problems. To be sure, general papers such as those of Webb (4), Chamberlin (5), and Craighead (1), and textbooks of compilations such as those of Keen (6, 7), Doane et al (8) and Graham (9) all emphasize the importance of species of the genus Dendroctonus in western forest entomology. In addition nearly eighty percent of the many unpublished research reports on file at the Berkeley laboratory are concerned with phases of problems in which species of that genus are involved. On analysis, however, the fundamental concept of the problem has not been that of insect damage and insect activity alone. Rather interest has centered on the ecological complexes centering around certain species of valuable host trees in which the bark beetles represent but one type of critical factor involved. The chief reason for considering those problems as pine beetle or bark beetle problems is that those insects stand out as predominant last or final forces which change the infested host trees from living to dead organisms. The destruction resulting from that change in many trees and over wide areas is the real problem.

No one factor can be pointed out as the critical factor in all trees or at all times or places. It is more likely that certain factors or combinations of known or even of unknown factors or combinations of factors may be the important ones at other times or under other conditions. It is merely for convenience that the important forest insect problems in California have been known as the pine beetle or the bark beetle problems. They might just as well have been called, at times at least, the engraver beetle, flatheaded borer, scale, site, climate, soil, precipitation, tree growth or health, tree age, tree or stand susceptibility, or even as the forest protection or management

problem, depending on which species of insect or which factor or element seemed the more important at the time. Research on the pine beetle problem has lead the forest entomologist into studies probing the character and relations of many of these factors or elements. It will be my purpose to review some of the objectives and results of recent research in order to describe how that work has gone on in attempts to solve some of the problems in western forest entomology.

THE SEARCH FOR AN EXPERIMENTAL TECHNIQUE

Bark beetle broods are difficult to work with. While the adults, eggs, larvae, and pupae are in infested trees they cannot be observed as they are hidden in the phloem under the bark. No way has yet been found to observe them without creating abnormal conditions under which subsequent normal development will not take place. Thus, from necessity and not from choice, much of the research has been of a type in which conditions affecting the experiment have been accepted and observed as they occurred under varying field conditions. Few, if any, of the many variables in the field environments could be adequately controlled. This has made necessary the collection and interpretation of large amounts of data, often without securing any definite impressions of trends or results because of the great range in their variability. For example, in attempting to obtain accurate figures for the ordinary simple calculations for attack and emergence ratios, Keen (10) concluded the following concerning counts made on 4,177 square feet of bark area from 979 western pine beetle infested trees:

"One of the first things to impress the workers in this field was the tremendous variation in emergence (64 plus or minus 50) and other events during any one year among different trees, and even on any one tree in different parts of the tree. At once it becomes evident that no general rule can be deduced from an intensive study of a single tree or a small series of trees and that valuable results were possible only through statistical methods involving data taken from a large series of trees in different areas, sites, and slopes during a long period of years."

The records Keen had available were taken over a period of thirteen years.

In forest insect research, as in other entomological work, plots can be selected and used for experimentation. However, in forest areas there is usually great variation in conditions even in adjacent or strictly selected plots. This makes interpretation of data difficult, often introducing the necessity for arbitrarily selected correction factors or analysis methods in order to judge the results of an experimental treatment. Replications of plot arrangements are possible, but great variation in all of the factors concerned make a large series necessary. Much of the experimental work and the dispersion habits of at least some of the bark beetles require relatively large sized plots each of which is costly to install and inventory.

Conditions such as those mentioned above have lead to a search for techniques in which standardization of experimental populations and control of at least some of the variables might be possible. Considerable work has been done by Miller (11) and Yuill (12) in the field of lethal temperatures and Beal (13), Whiteside (14), and others in the field of developmental temperatures. By using naked full grown larval populations or broods in logs and special temperature control apparatus, those workers have found the points at which western and mountain pine beetle larvae die, and how many developmental temperature units are required, under laboratory conditions, for development in the fourth instar, prepupal and pupal stages. The existence of a temperature bar in the prepupal stage - some requirement which prevents pupation of full grown larvae even though growth in other stages may be taking place - also was discovered. Temperature relations of brood development in infested trees could not be measured as well, for the bark factors, the daily ranges of temperatures, and other variables made field measurements much less accurate than those made in the laboratory. However, within limits it was possible to

measure the temperature requirements for the development of some of the younger larval and the egg stages, phases of work which could not adequately be investigated in the laboratory.

This and similar work has shown that the conditions under which experimental populations are raised influence to a considerable extent the lethal temperature points and has brought up the question of the possible existence of geographical or host biological strains within a species. Bongberg (15), by measuring head capsule widths of western pine beetle larvae, found that broods in different trees varied considerably. Broods from naturally infested trees had larger measurements than those from artificially infested logs. Thus experimental populations reared in logs do not have normal head capsule measurements and presumably may not be normal in other respects as well.

In experimentation with both the western pine and the mountain pine beetles, nutritional factors have often been suggested as important factors to control or standardize in rearing experimental populations or in developing techniques. Jeffrey (16) found, by sampling highly susceptible and insect resistant types of host trees that larger proportions of the invert sugars dextrose and levulose occurred in the phloem of the susceptible trees. Following infestation of these trees by the western pine beetle the higher sugar concentrations in the phloem decreased until, when they became less than those of the dry outer bark the developing brood migrated to and continued feeding in the food stratum having the higher sugar concentrations. However, artificial media having a composition as similar to phloem as it was possible to secure failed to be suitable food for developing western pine beetle broods.

It has long been known that bluestain fungi (Ceratostomella spp.) are intimately associated with bark beetle infestations and Person (17) found that a yeast also was a constant associate of the western pine beetle. Attempts to rear western pine beetle brood on artificial media with or without these associates (18) failed to indicate that they had anything to do with brood development. To date all attempts to rear western pine beetle broods from egg to adult, either on artificial media or on natural host materials in laboratory glassware, have been unsuccessful. Struble (19) reared adults of D. monticolae from the egg to the adult stage on strips of fresh phloem, but found that they were noticeably abnormal in size and that experimental populations could be secured only at considerable cost and effort in this manner.

In summing up the work to secure standardization of experimental populations and techniques it can be said that much has been learned concerning the requirements of bark beetle broods, but that no practical method has yet been found to produce standardized populations of known normality. Broods can be reared fairly easily to maturity in natural host material such as logs, but the question of the abnormality of the resulting populations cannot be easily dismissed. The nutritional factor seems to be one of the most important, the secrets of which have not yet been discovered. The nutritional factor seems to be such an important one in the problem of the selection of host material for attack by the several species of insects that the determination of the normal nutritional requirements of developing broods would go a long way in making possible a more accurate interpretation of the role each species plays in the death of its host tree.

THE SEARCH FOR AN UNDERSTANDING OF FOREST INSECT POPULATION REACTIONS

Variations in loss from year to year and from area to area is the rule in forest insect infestations as in outbreaks of other insects. In the case of the mountain pine beetle populations in sugar pine, the population levels of that species seem more closely related to the amount of subsequent infested host material than is the case in western pine beetle infestations of ponderosa pine. Population reductions secured artificially by control work in ponderosa pine forests often have had little effect in reducing subsequent losses. At what are known as peaks of infestation cycles western pine beetle population and loss levels are high, attacks are vigorous, and the species predominates as a factor causing the death of relatively large groups of thrifty trees. Usually these high population levels are ineffective as experience has shown that subsequent losses and activity can be expected to be considerably less. Interpretations of these phenomena have been varied.

It has long been noted that fluctuations in western pine beetle populations generally vary directly with fluctuations in loss levels. That may merely mean that the western pine beetle is the predominating population in point of numbers and that ^{that} condition may be a result rather than a cause. However, the fact remains that vigorous western pine beetle attacks on vigorous trees during the peaks of infestation cycles are definitely causes of heavy loss. Overmature, decadent and weakened trees are chiefly the types of trees attacked at other phases of the loss cycles. What are the reasons for these apparent changes? What are the factors or conditions which lead to the group killing outbreak form of attack? Those attacks seem to be products of previous reactions. The testing of possible factors has been one of the most important assignments on which western forest entomologists have been working.

Parasites and Predators: Under California conditions few parasites of either the western or mountain pine beetle are known and none appear to be effective control factors. Under some conditions and in some years fungi are found in the egg galleries and larval burrows. Casual observations have indicated that brood failure often is associated with their presence, but their importance has not been determined. Struble (20) studied certain coleopterous predators of the western pine beetle and has just completed work on two predators of the mountain pine beetle in sugar pine. Person (21) studied the possible control effects of a clerid predator associated with the western pine beetle in infestations of ponderosa pine. In general the conclusions reached as a result of all this work is that, although these predatory insect species kill bark beetle broods and exert some control effect, they do not appear to be critical control factors, particularly when other conditions favor the production of bark beetle populations. Similar conclusions have been reached concerning the activities of birds, chiefly woodpeckers.

Species Interrelations: Early in the history of forest entomology in California it was noted that several species of phloem mining insects usually were associated in attacks on forest trees. As early as 1918 Miller (22) studied these relations. In the epidemic outbreaks of 1913 and 1931 in the central Sierra region of the state attacks by the five spined engraver beetle (Ips confusus Lec.) definitely preceded and facilitated succeeding western pine beetle infestations producing high bark beetle population levels and excessive timber losses.

In ponderosa and Jeffrey pine stands of California infestation of trees by the flatheaded borer (Melanophila californica VD) often precede attacks by other species of insects. Under endemic infestations this type of infestation appears to be important, particularly in the older weakened or

unhealthy trees. Often the trees in which flathead broods occur act as a center of attraction to western pine beetle populations which not only infest that tree, but are likely to attack and kill several nearby healthy trees as well, particularly if the pine beetle population level is high at the time. Research by West (23) has shown that the life history of this flathead species includes a so-called incipient larval stage which may exist in the phloem of green trees for periods of from one to several years. Infestations thus occur normally in green trees, often several years in advance of attacks by the western pine beetle. However, the question as to what effects the incipient infestations have on the host tree and what part they may play in facilitating subsequent infestation by other species and the ultimate death of the host tree has only partially been investigated.

The Oregon engraver beetle (Ips oregoni Eichh.) is another species which, however, is involved chiefly in the epidemic rather than the endemic phases of infestation cycles. They fill in the uninfested tops of trees which have been attacked by the western pine beetle, particularly when the less cycle is approaching its peak. At that time the species appears to play a secondary role. However, the same species also topkills green trees, particularly in the period following the peak of the less cycle and at that time are a factor of considerable importance in preparing many of the trees for subsequent attacks by the western pine beetle.

A more recent interrelation concerning which little is known is that of the bark infesting scales (Matsucoccus spp.) and bark beetle infestations. ~~work on the complex infestation of the~~ Work on forest scales and on their possible importance is being carried on by McKenzie.

All of these interrelations are interesting although their meaning is not yet clearly understood. Much more work remains to be done before the part they may play in infestations and loss cycles can be fully determined. Perhaps certain types of relations are concerned in the building up of high western pine beetle population levels. Perhaps some are indicative of changes in the roles of the several species, changes which seem likely to be a normal occurrence. Even though the true values and meanings of these relations remain obscure it is entirely possible that a knowledge of existing interrelations of several species may be of value as an index of current infestation tendencies.

Physical Environmental Factors: There is a strong and widespread belief that a wet season is followed by less damage from forest insect activities and dry years are followed by outbreaks and heavy infestations. Keen (24) and other authors have studied the subnormal tree growth of the period of 1917 to 1936 which occurred during a period of accumulating precipitation deficiencies. Person (25) determined that slower growing trees are those which are more susceptible to bark beetle attacks and the survey record of bark beetle losses of the past twenty years in California attests to the seriousness of the infestations which have occurred during the dry period. However, it has been difficult to make direct correlations of specific climatic factors and loss levels. Perhaps one reason for this lack of correlation is a lack of pertinent factor stations in forested environments. Probably an important reason is that several or many instead of one or a few factors are operative, the effects of one set often obscuring the effects of others. For that reason Hall has established weather stations in selected forest environments and is gathering data pertinent to the problem of the relations of climatic and site factors and loss.

Host Relations: Throughout the history of formal research on the forest insect problems of this region the condition of the host trees previous to infestation has been considered a factor of great importance. Many writers have noted the preference for overmature slow growing or decadent trees for attack by the western pine beetle. Person (25) found that selection may be due to the effects of the site on which the trees were located or to the characteristics of the trees themselves. Ponderosa pines between 20 and 30 inches in diameter which were slow growing were the preferred hosts. Dunning (26) noted that mature and overmature types of trees in his classes 4 and 5 were more subject to losses from insect attack than from other causes. Keen (27) found that "in general, the trees more susceptible to attack are the weaker, less vigorous individuals and to a certain degree, those more advanced in age". Whereas Dunning's classification of pine trees into seven classes was primarily concerned with selective cuttings to attain silvicultural objectives, Keen's classification which described 16 classes or types of trees, was developed to more closely define the susceptible tree types so that both silvicultural and insect control objectives might be achieved.

Both classifications utilized age of tree, crown form and size, and position in the forest canopy as characters of future productiveness, vigor, or susceptibility to insect attack. More recently Bongberg (28) has been using a highly selective four-class risk marking developed to pick out only the highly susceptible individuals in ponderosa pine stands so that they might be removed and utilized before their values were destroyed by forest insect infestations.

This phase of research on the western pine beetle problem had as its objective the control of forest insects or the prevention of damage by picking out the susceptible individual trees or types of trees so that they

might be removed and utilized. In order to apply these classifications there should be some basis for selecting certain areas over others and a complete knowledge of which stands show the greater potential hazard from barkbeetle attack and loss so that the application could be made on an intelligent basis adapted to the varied conditions of different areas. In order to secure this information Johnson (29) has conducted an Inventory of Hazard on about two and a half million acres of forest land in northern California gathering information concerning the past loss and the present construction of the stands in terms of the proportions of susceptible and high risk types of trees. This information is proving to be valuable in planning for widespread forest protection programs as well as for planning the protection and utilization of individual timber blocks or smaller acreages.

The Search for Control: While the control of barkbeetle populations remained the objective, research on direct methods predominated. The felling of infested trees and the peeling and burning of the insect infested bark long remained the standard method which today under certain conditions and in many areas finds a wide and fairly effective use. Improvements in technique and tests of variations in the method have been the objectives of much of the research on direct control. Solar heat was tried to eliminate the use of fire in summer control work. Burning the bark in pits also was tested in order to reduce the fire danger. Burying bark in the soil and submerging infested logs in water were two other methods tested to determine if broods could be killed cheaply. Spraying of external bark surfaces with penetrating oils was tested with only partial success. The removal of infested logs for utilization of merchantable values and destruction of the broods at the lumber mill was studied by Patterson (30), Keen (31), and

Johnson (32) in an effort to reduce control costs. However, few of these changes greatly increased the effectiveness of the direct methods of control or decreased control costs.

Person (21) carried out experiments using solar heat to kill western pine beetle populations in ponderosa pine and favor the survival of clerid predators. He concluded that the extra cost was not justified by the results. Struble (33) reared the green trogositid (Temnochila virescens (Fab)) and the red bellied clerid (Enoclerus sphegeus Fab.) in the laboratory for release to control mountain pine beetle infestations in sugar pine, but found the costs excessive and the results inconclusive.

In the field of indirect control and the prevention of loss, it long has been known that the logging of an area, removing as it does, the more valuable older types of trees and leaving the less valuable, but also less susceptible, younger and thriftier trees under most conditions results in satisfactory forest insect control. Exceptions are known, for in marginal or tension zone areas even the thrifty reserves have been subjected to depletions and forest insect infestations have gone on after logging.

The use of Dunning's selective cutting system has been given wide application in California as for many years it has been the standard Forest Service method of cutting. Where it has been applied it usually has secured good control for between 70 and 80 percent of the stand, including practically all of the susceptible types of trees, are removed in the operation. However, such a heavy cut means that only a relatively small acreage is covered each year and, throughout the region the experience has been that the losses on uncut areas have totalled as much or more than the amount of timber that has been utilized. The problem has thus been one of increasing the treated acreage.

Application of Keen's classification in selective cutting probably would result in removing between 40 and 50 percent of the stand volume and would provide for an increased coverage at a more rapid rate. Such a cut is sufficiently great to modify stand susceptibility to a considerable extent and should exert a marked control effect as well as fulfill some silvicultural objectives. Unfortunately there has been no opportunity to test that method of cutting in California so that its control effects have yet to be determined in practice.

The light risk marking, which is being tested by Bongberg in a sanitation-salvage control experiment on the 10,000 acre Black's Mountain Experimental Forest in cooperation with the California Forest and Range Experiment Station, removes only 15 percent of the stand. It has run for three years and is yielding very promising control results. High risk trees are removed and the green logs are taken to a mill for utilization. Losses on treated areas have been reduced by 72 percent for a three year period and the indications are that a longer period of adequate protection is possible. It is too early to state the total period and the total amount of protection that can be secured by the use of this indirect control method, but research is being continued. The light cut probably will make a more rapid area coverage possible, remove the objections of slow area coverage which limit the effectiveness of other methods of selective cutting, and provide for the utilization of salvaged logs.

WHAT LIES AHEAD

Emphasis has been placed on the pine beetle problems, chiefly the western pine beetle problem in the virgin pine forests of this region. Bark beetle problems are and have been for a considerable period, the more

important problems. It is evident to those connected with the work that research has made great advances, particularly in advancing our knowledge of what the problems are and in making indirect control measures realities instead of mere ideas.

There are, however, other problems which face us now or which it seems certain will be important ones in the future.

Many forest areas in the state are valuable primarily for recreational use. Several problems are concerned with that use and with the protection of stands in which individual trees have aesthetic attributes of high monetary value. It is evident that these recreational areas must be considered as park areas and the individual trees as shade trees for purposes of insect control or prevention. It is obvious that methods used to control forest insects in commercial forest areas will not be adequate or satisfactory under such conditions. Considerable work is needed on this type of problem.

The acreage of cutover lands is increasing rapidly. In another quarter of a century we can expect that problems of second growth stands will be outstanding problems in the field of western forest entomology. What are the problems which are likely to arise? How can we solve them and maintain entomological factors under satisfactory control?

Species of trees such as white fir and lodgepole pine now have a relatively low commercial value in this region. Will they be valuable forest resources in the future? If they become important sources of forest products what can be done to control infestations which now are known to be causing excessive losses? Nothing is being done at this time, but enough is known about the ecological complexes associated with infestations of those species of trees to warrant a judgment that difficult control problems are involved.

Last but not least, the planting of forest trees has received considerable impetus in this region within the past ten years. Reforestation activities are likely to be more important in the future forestry picture. Already a hitherto unimportant species of weevil has nearly wiped out most of the values in one established plantation. Will other forest insect problems arise in connection with this work? What will they be and what can be done about them?

These are but a few of the interesting problems which seem certain to become more important as time goes on. Undoubtedly they will be as great a challenge to future forest entomologists as the pine beetle problems of virgin stands are to the forest entomologist of today.

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